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THE TRANSITION OF FOSSIL FUEL AS A SOURCE OF ENERGY TO RENEWABLE ENERGY

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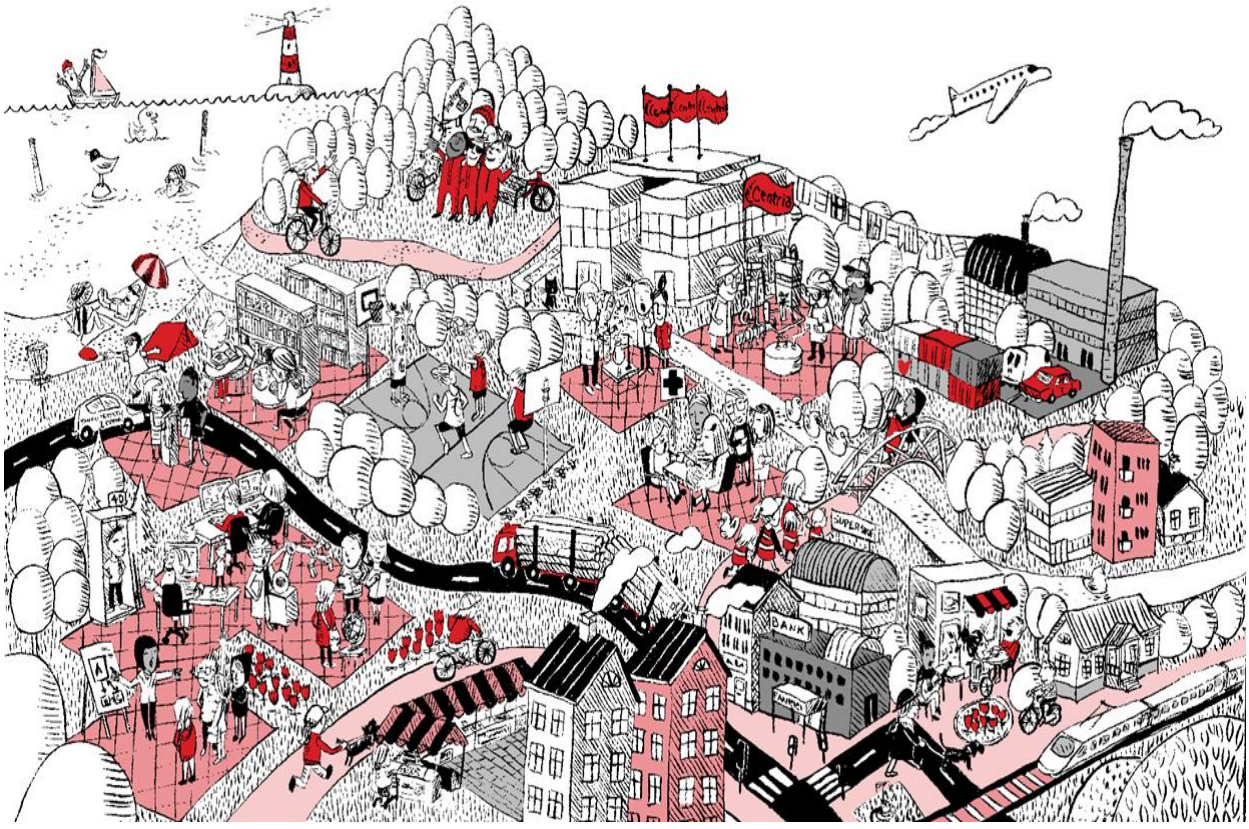

ABSTRACT

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Thousands of years ago, fossil fuels were the main source of energy in the world. These fossils include coal, oil, and gas with the time of discovery, and exploitation of the type of fossil being different for each country. Each country's consumption of a fossil type depended on the availability, the necessary technology to harness the fuel, and trade based on imports and exports. From the Industrial Revolution, fossil fuels had and continue to play a dominant role in energy systems today. The burning of these fuels for energy production accounts for about three-quarters of global greenhouse gas emissions and is a threat to human health through air pollution. With the negative impact of fossils, there is an urgent need to transition from these high carbon sources of energy to low carbon sources to save the environment and preserve human life. These low carbon sources also known as renewable sources are the hope to preserve the environment and are one of the main focuses in the world's energy system. The switch to renewables has not been an easy transition in many parts of the world today because of factors like availability of low carbon resources, technological innovations, finance, right knowledge, and governmental policies that play a significant role in enhancing and affecting the transition to renewable energy. Aside from environmental and health-associated reasons, many countries are in this transition to gain energy security to meet the needs of their growing population and increase energy demand. Therefore, the transition is possible but will be slower in some developing countries, but with new sources of energy becoming competitive, the switch can be dramatic.

Keywords
Coal, fossil fuels, gas, GPD, low carbon sources, nuclear energy, oil, per capita, primary energy, and renewables

CONCEPT DEFINITION

GPD

Gross domestic product is the monetary value of all finished goods and services produced in a country in a specific time and includes anything that is produced within that country.

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1 INTRODUCTION

Fossil fuels are naturally occurring energy reserves, found deep inside the earth's surface which is formed from the remains of plants and animals millions of years ago due to the anaerobic decomposition and sedimentation of organic matters. Fossil fuels are a nonrenewable source of energy, with examples such as coal, crude oil, petroleum, natural gas, and their derivatives. These fuels are used as energy to produce electricity and as fuels for automobiles.

Fossil fuels have irreversible and devastating consequences on the environment. Research has shown the impact these fuels have on our world today and are disliked due to their non-renewable and unsustainable nature which is a matter of concern between different nations of the world because of their nonuniform distribution. Nowadays, technological advancements and more efforts are being put in place to replace fossil fuels with renewable energy sources, which brings much desirable health, environmental, and economic benefits. This thesis work explains the different examples of fossil fuels, the global consumption of these fuels, future developments of fossil fuels, and the future of renewable energy for generations to come.

2 OVERVIEW OF FOSSIL FUEL

Fossil fuels are formed from dead organisms (plants and animals) that were found on the surface of the Earth millions of years ago. Fossils existed as organic matter once but different conditions such as temperature, pressure, rock, and sediment have led to the formation of several types of fossil fuels. Chemically, fossil fuels are hydrocarbons that consist of carbon, hydrogen, sulfur, oxygen, nitrogen, and mineral matter. This mineral matter turns into ash when burnt. The composition and amount of these elements vary for different fossil fuels. Fossil fuels are a finite source of energy that cannot be replaced when extracted making them nonrenewable and unsustainable and because we use fossil fuels much faster than they can be formed and form over millions of years, sources can run out making fossil fuels a limited source of energy. (Owens, 2019).

In 1597, fossil fuels started as a theory by Andreas Libavius who conceptualized the idea of combining the remains of plants with heat and pressure up till 1763 when the theory was further researched and explored. Fossil fuels over time became increasingly popular and used all over the world. By 2017, fossil fuels constituted most energy supplies with sources of fossil fuel including petroleum and natural gas combined and summed up to 85% of the fossil fuel in primary consumption. Some forms of petroleum, coal, and natural gas were used by different countries in the world based on historical records and archaeological finds. The use of these fuels in ancient times was limited due to insufficient knowledge and technology but the volume has rapidly increased due to exploration, extraction, processing, trading in industries, and the industrial revolution which has managed to make the most of the fossil fuel resources which is being extracted and used in everyday life. (Kool, 2020).

Fossil fuel tends to be environmentally unfriendly due to oxidation when they are being burnt with the creation, usage, and consumption being controversial. The emissions produced from the use of these fuels from many day-to-day activities have continued to increase and the environment is not able to keep up and absorb the amount of carbon dioxide produced. But with technology, innovation, and research alternatives to fossil fuels are being explored and developed to prevent air pollution for a cleaner and more sustainable environment. (Owens, 2019).

The different types of fossil fuels are formed based on the combination of organic matter that was

present, how long it was buried, the temperature and pressure conditions that existed as time passed. The three major forms of fossil fuels are coal, oil, and natural gas. Oil and natural gas are fossil fuels found underground and are formed from marine microorganisms, and coal is found in rock layers formed from ancient swamp vegetation. The chemical structure of these fossil fuels varies depending on which fuel type it is. (With the molecules in coal larger than those in natural gas and oil). Thus, coal is a black or deep brown solid, oil is a liquid and natural gas is a gas at room temperature and consists mostly of methane and other small hydrocarbons. Today, fossil fuel industries mine for these energy sources and burn them to produce electricity, refining them to be used as fuel for heating and transportation. (National Geographic, 2012).

2.1 Coal

Coal is solid brown or black material rich in carbon. It was formed by the accumulation of organic plant matter through the activity of microorganisms. The organic matter was converted to peat which is the precursor material from which coal is obtained. There exist different coal types based on the type of organic material. Coal occurs most often in stratified sedimentary deposits and the hardening and compaction of these altered plants matter to produce coal which is 70% by volume or 50% by weight of carbonaceous matter. Coal is one of the most important primary fossil fuels worldwide which is used in the production of electrical power using steam generation. The liquefaction and gasification of coal produce gaseous and liquid fuels that can be transported easily and stored conveniently in tanks (Kopp, 2022).

Coal is a cheaper alternative fuel and produces more energy than wood fuel when burned. In the 18th century, coal-powered the industrial revolution by providing steam and the power needed to produce and generate electricity. Coal was used as fuel in steamships, and trains to transport items that were used for trade. The use of coal during the industrial revolution expanded in the iron and steel industry and the introduction of its use in steam engines. (Fernihough & O'Rourke, 2020). Coal is used directly for heating and indirectly for electricity production. Around the world and most developing countries, it is the leading energy choice, and its consumption worldwide has increased until now when the world is transitioning into more renewable sources and clean energy. In addition, coal is also used in the production of synthetic materials such as plastics, tar, and fertilizers (National Geographic, 2012).

However, the burning of coal has some negative effects on our health and environment which are still being investigated. Coal as compared to other fossil fuels has a higher carbon content of 78% and when burned combines with atmospheric oxygen to produce carbon dioxide which is a major green-house gas and a cause of global warming. (Hong & Slatick, 2019). In the natural carbon cycle, to keep the circulation of carbon balanced, carbon and carbon dioxide are constantly being recycled between the land, the ocean, the atmosphere, and all living decomposing organisms. This carbon dioxide emitted during the combustion of coal absorbs and retains the heat in the atmosphere thereby causing a rise in the temperature and a build-up of greenhouse gases which affect our climate and ecosystem. The burning of coal releases other gases like sulfur dioxide and oxides of nitrogen which are a cause of acid rain, respiratory illnesses, and smog (National Geographic, 2012).

2.2 Oil

Oil is a smelly, yellow to black liquid that is found in large quantities in underground reservoirs which are often used as a fuel or raw material in the chemical industry. Oil also known as petroleum or crude oil does not exist in the deep, black pool. Oil exists in liquid or gaseous form in this underground oil formation as tiny droplets in open spaces called pores inside sedimentary rocks and near the earth's surface in tar (or oil) sands. This oil is drilled and refined into various petrochemical products such as plastics, polyurethane, solvents, and other intermediate products and used as fuel transportation which is the fastest-growing element and accounts for half of the oil demand. In the world's primary energy supply, oil accounts for the largest share as compared to other power-generated fuels. Oil products are more flexible and can easily be transported and stored and in most parts of the world, the oil serves as residual fuel. (Robert, 1998)

Oil is composed of hydrocarbons (hydrogen about 13% by weight and 85% of carbon), nitrogen, sulfur, oxygen, and metals such as iron, nickel, and copper. From millions of years ago, the organization of molecules in the hydrocarbon was based on the composition of algae and plants that were involved in the decomposition. The amount of heat and pressure the plants were exposed to contribute to the variations that are found in hydrocarbons and crude oil. Due to these variations, the crude oil pumped from the ground can consist of hundreds of different petroleum compounds with light oils containing up to 97% hydrocarbons, heavier oils and bitumen containing 50% of hydrocarbons, and larger quantities of another element. To make useful products out of crude oil, it is important to remove other

harmful elements that might contaminate the final product and also to refine the crude oil. (National Geographic 8 November 2012)

2.3 Natural Gas

The remains of plants and animals built up in layers on the earth's surface and ocean floors mixed with silt, sand, and calcium carbonate, and overtime pressure and heat changed this organic material into natural gas, petroleum, and coal. Natural gas in some places moved into large cracks and spaces between layers of overlying rock. And this form of gas is called conventional natural gas. Other types of natural gas include unconventional natural gas which is natural gas that occurs in tiny pores within formations of shale, sandstone, and sedimentary rocks. Some natural gas occurred also with deposits of crude oil and is called associated natural gas. Natural gas contains different types of compounds with the largest component being methane. Natural gas is used mostly in generating heat and electricity with other uses in industrial, commercial, residential, and transportation purposes as fuel. (Linquip team 25 March 2021). Natural gas is transported by pipelines from the production fields to its various consumer sites.

Natural gas is stored in large underground storage systems like gas wells where the gas remains there until it is added back into the pipeline and used to heat homes during the winter times when the demand for natural gas is greater or when people begin to use more gas. Natural gas when chilled, to very cold temperatures of -162^0C changes to liquid form called liquified natural Gas (LNG) which can be stored in this form and, loaded onto tankers and moved across the oceans to be delivered to other countries. Natural gas like other fossils affects the environment when it is produced, stored, and transported and the gas which consists of mostly methane can sometimes leak into the atmosphere from wells, storage tanks, and pipelines which is also an environmental concern. The gas when burnt, releases carbon dioxide which is a very important greenhouse gas but compared to other fossil fuels it burns more cleanly and has fewer emissions of sulfur and nitrogen which leaves almost no ash particles. Being a clean fuel, the use of natural gas especially in electricity generation has grown and is expected to grow even more in the upcoming years. (Energy Information Administration 2021).

3 GLOBAL PRODUCTION AND CONSUMPTION OF FOSSIL FUEL

The burning of fossil fuels for energy began around the onset of the industrial revolution with the consumption of these fuels changing significantly over the years in terms of what and how much we burn. Energy consumption in most countries comes from their energy supply but not all countries have the reserves to produce this energy themselves. The production of fossil fuel in a country can be more than how much of that fuel is being consumed, and the consumption of a type of fossil fuel can be more than the amount of the fuel produced in that country. To know the role fossil fuels are playing in the energy system of a country, it is important to understand where, and which fossil fuel is being extracted in what country and where the energy is being consumed. The figures below represent the production of fossil fuels before trade between countries. (Ritchie & Roser 2020).

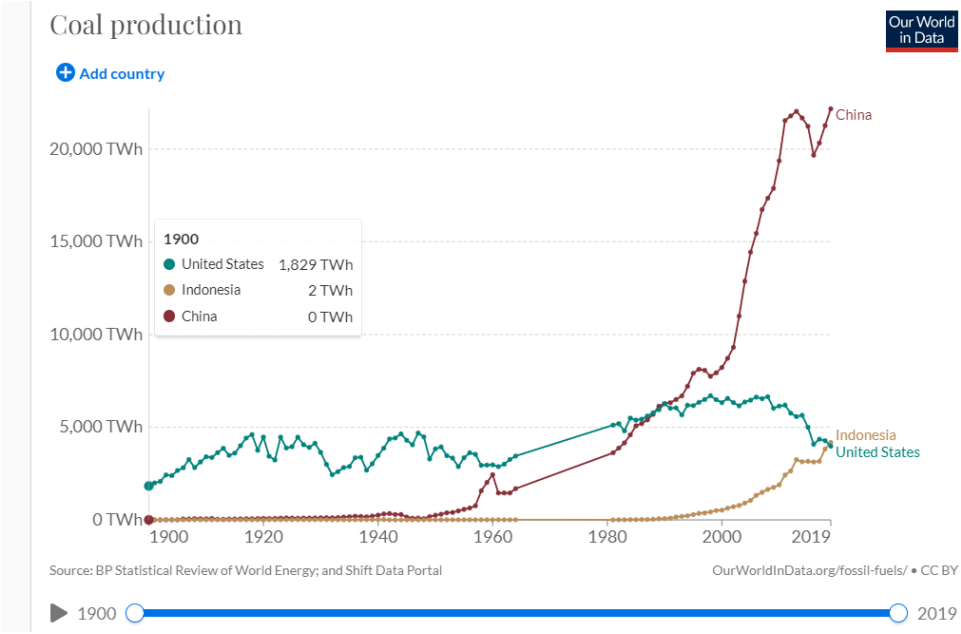

FIGURE 1. Worldwide production of coal from 1900-2019 (Ritchie & Roser 2020).

From figure 1 above, the top three leading countries in the production of coal are China with 22,171TWh, Indonesia with 4180TWh followed by the United States with 3972TWh in the year 2019. But it is observed that the production of coal in China only began in around 1940 but the United States

had already begun its production of coal of about 1829TWh by 1900. (Ritchie & Roser 2020). Due to the increasing population of China and its desperate need for electricity China has over the years expanded its coal production to meet up the needs of its growing population making China the world's largest production and consumer of coal. (Bradsher, 2021).

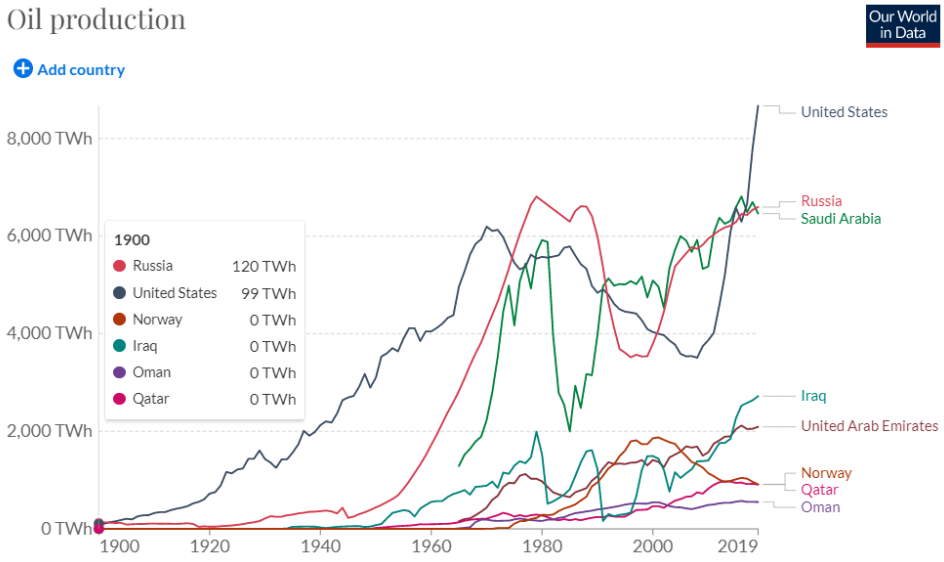

FIGURE 2. Production of oil worldwide from 1900-2019 (Ritchie & Roser 2020).

From figure 2 above, it is observed that Russia was the first country that first drilled oil with the United States leading to a date. However, its production of oil has been fluctuating by observing a rise and fall in its production. In 1945, the production of oil in Russia steadily increased due to the discovery of new oil regions and the Soviet Union. In 1979 the production of oil in Russia was at its peak leading in the world's production of oil with a production of 6810TWh of oil. (Ritchie & Roser 2020). In 1980, the Soviet petroleum industry entered a period of decline due to the depletion of existing wells, caused by intensive drilling, and a lack of investments in the exploration of new deposits. The fall was also because of the fall of domestic demand for oil, export possibilities, and drilling volumes (Egorov, 2019). But in 1999, production volumes were restored, and the production of oil stabilized. From the chart, it can be observed that Saudi Arabia started producing oil in 1965 and the production of oil in the United States steadily increased from 2007 until 2017 and is the world's largest producer of oil to date.

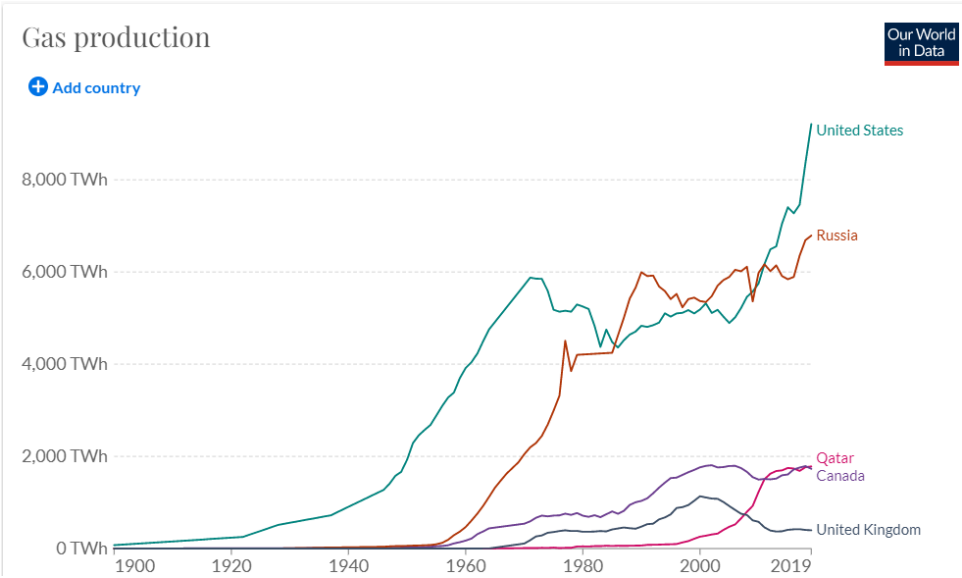

FIGURE 3. Production of gas worldwide from 1900-2019 (Ritchie & Roser 2020).

Figure 3 shows the variation in the production of gas over the years with the United States being the country with the highest production in gas. Today, natural gas is a vital component of the world's energy supply. Natural gas currently supplies about 41% of the energy used in the U.S industry and supplies about one-half of the energy consumed by residential and commercial customers. Globally, natural gas is the second-largest source of electricity production because it emits less carbon dioxide per unit of energy, but the world is shifting away from gas towards low carbon sources and nuclear energy. (Ritchie & Roser 2020).

The consumption and type of fossil fuel used for energy have significantly changed in terms of what we burn and how much of it we burn. Coal is the world's oldest and still a dominant industrial source of energy across the world, especially within the electricity mix. But due to the excessive amounts of carbon dioxide and local air pollution coal produces per unit of energy, many countries are committing to phasing coal power out of their electricity mix and its consumption is falling while oil and gas are still growing quickly. Oil is the most consumed fossil fuel and the world's largest energy source, especially in the transport sector followed by coal and then natural gas, which is the cleanest, safest, and most useful of all three energy sources. As an energy source, natural gas for decades now has lagged oil and coal but as a replacement for coal in the energy mix, its consumption is growing rapidly in many parts of the world today. The consumption by type varies in different countries based on how

much they produce; how much is in their reserves and how much the country is looking towards sustainable development in eliminating the amount of greenhouse gas emissions. (Ritchie & Roser 2020).

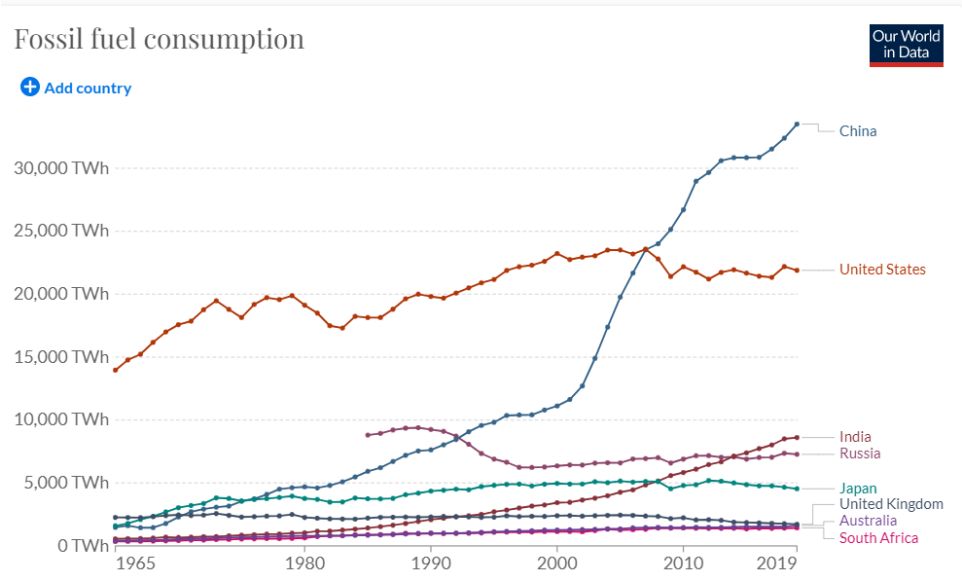

FIGURE 4. Fossil fuel consumption by countries (Ritchie & Roser 2020).

China and the United States as seen from figure 4 are the countries that use the most energy from fossil fuels due to their large population, how much they produce, and how much they import. The consumption of these fossils at the country level is different from the actual fossil fuel consumption per person and varies from country to country. From figure 5 below, the largest consumers use more than ten times the amount of fossil energy than some of the smallest consumers.

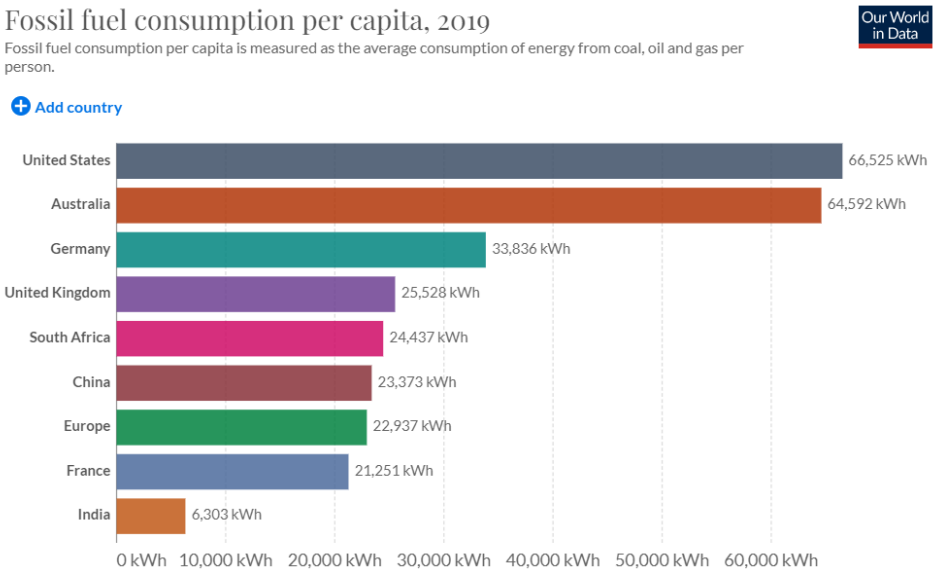

FIGURE 5. Fossil fuel consumption per capita (Ritchie & Roser 2020).

4 FUTURE DEVELOPMENT IN FOSSIL FUELS AND INTRODUCTION TO RENEWABLE ENERGY

Today, the world's energy mix is still very much dominated by fossil fuels with the largest amount of energy from oil, followed by coal, gas, and then hydroelectric power. Fossil fuels account for more than 80% of the world's total energy consumption and the burning of these fuels has led to around three-quarters of global greenhouse gas emissions and climate change. Fossil fuels are also a major contributor to local air pollution which accounts for millions of premature deaths recorded each year. The world, therefore, needs to shift away from these high carbon sources of energy to low carbon sources of energy which are nuclear power and renewable technologies to reduce carbon dioxide emissions and limit the global average temperature change. (Ritchie & Roser 2020).

With fossil fuels being a finite resource, we may or may not have reached peak oil (the point at which demand exceeds supply) but with the increase in human population and our rate of consumption of fossil fuels it is becoming increasingly difficult to locate and extract new sources of energy. In 2008, many experts agreed that we did reach peak oil but with external factors creating fluctuations in demand, it is difficult to predict exactly when we will run out on our energy source from fossils. Fossil fuel eventually will run out and it will take some 10,000,000 years to replenish what we have used in around 150 years, reasons why the shift to renewable energy is required. (Mason, 2021).

Renewable energy is energy generated from natural sources that do not run out and can be recycled. These natural sources are solar power, biomass, wind power, hydropower, biofuels, geothermal energy, and tidal power. Biofuel is the production of fuel either from the extraction of residues or decomposing matter as a result of anaerobic processes. Biofuel can also be produced by the direct processing of raw materials by extracting its natural oils and processing them into a type of fuel. Biomass on the other hand is a form of biofuel that comes from waste organic material such as wood and other plant matter. Biomass is not a derivative of a product that results from processing. examples include scrub, chopped wood, grasses, leaves, and other raw materials that may burn to produce energy. (Mason, 2021).

Geothermal power is one of the most interesting concepts of renewable energy where thermal energy is being harnessed from the earth’s crust. Another source of energy is hydropower which is derived from the potential energy of dammed water which is tackled to rotate a turbine that drives a generator to produce electricity. Hydropower is the world's major source of renewable energy to produce electricity. (Yakoubou, 2020).

Solar energy is energy that comes from the radiation from the sun which is converted into useful electrical or thermal energy. And wind energy is energy derived from the wind which is converted into useful electrical or mechanical energy. (Board of investments 2018). Solar energy has been harnessed by humans for thousands of years and according to the National Renewable Energy Laboratory (Lora, S 2018), more energy falls on the earth from the sun in an hour than the amount of energy per capita that is used in the world in one year. Energy from the sun is used to heat homes and businesses, and power devices. These renewable energy systems produce little or no greenhouse gases or air pollutants if they are responsibly sited. (Shin, 2018).

5 ONGOING AND FUTURE DEVELOPMENTS IN RENEWABLE ENERGY

In the world today, renewable technology is rapidly growing in the energy systems with the energy mix consisting of a diverse range of energy sources such as coal, oil, gas, hydropower, wind, biofuels, solar and other forms of renewable energy. In the 1800s right up to the mid-19th century the burning of traditional biomass was the most dominant energy source used across the world. Until the time of the industrial revolution, the use of traditional biomass shifted and brought about a rise in the consumption of coal, followed by oil, and then gas, and around the 20th century, hydropower. The transition of one energy source to the other has been slow over the years and the shift from fossil fuels to low carbon energy is quite challenging as compared to the past. With most countries in the world still very much dependent on fossils for energy, fossils sum up to about 80% of the world's total energy consumption. (Vaclav, 2015).

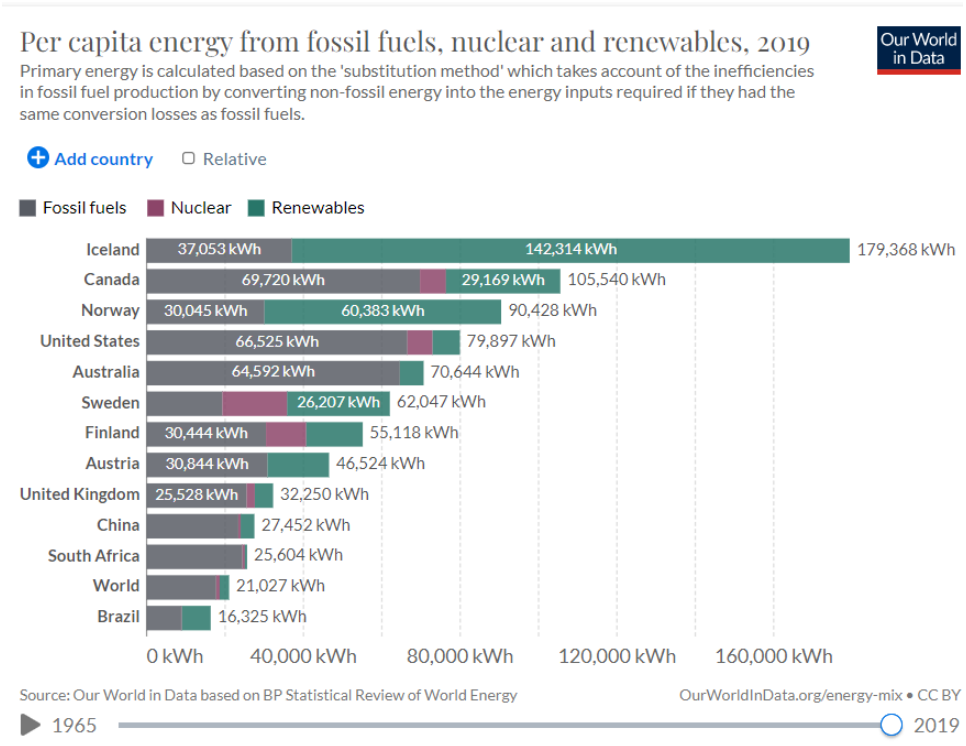

FIGURE 6. Breakdown of Energy mix by countries from 1965-2019 (Ritchie & Roser 2020).

Figure 6 represents the breakdown of the energy mix in terms of per capita consumption by country with the higher breakdown by fossil fuels, nuclear, and renewables. In 2019, low carbon sources summed up to 15.7% of the global primary energy. These low carbon sources include nuclear energy (4.3%) and renewables (wind, solar, bioenergy, geothermal, wave, tidal, and hydropower) 11,4%. Hydropower and nuclear-combined sum up to 10.7% and accounts for most of our low carbon energy with wind and solar growing quickly which means we are a long way away from the goal to shift towards low carbon energy sources. (Ritchie & Roser 2020).

In 2019, Iceland was the leading in renewable energy in the world with 92% of its total primary energy consisting of renewables, 7% from oil, and 1% from coal and other sources. Today, Iceland is a leader in the application of renewable energy worldwide with 81% of its primary energy requirements for electricity, heat, and transportation from hydro and geothermal sources. (Gipe, 2012). Iceland's transition from fossils to renewables only started in the 20th century with only a few megawatts of power generation but until the early 1970s, imported fossil fuel was the largest share of the country's energy consumption. The shift to renewables in Iceland was not based on the importance of renewables for climate change, and clean energy but so that they could have energy security with the fluctuations in oil price and energy cost affecting the world markets. The country's location and geography make it possible to harness considerable resources of both geothermal energy and hydroelectric power to generate energy sustainably without emitting greenhouse gases. (National Geographic 8 November 2012). Although Iceland in the 1970s was a small and peaceful country it lacked foreign rule, basic infrastructure, experience in taking major energy projects. It also, lacked experienced institutions to provide critical financing, and knowledge about the potential of its resources making its success not assured. Today, cohesion between municipalities, government, and the public is working together in exploring and exploiting its green resources for clean energy and energy security. In Iceland, 100% of its electricity is generated from renewables with 75% from hydroelectric power and 25% from geothermal energy. (Logadottir, 2020).

In many countries, renewable energy is playing an increasingly vital role in the decarbonization of energy systems. In Germany and UK, renewable energy sources accounted for about 44% of electricity consumption in the first half of 2019 for the first time surpassing the total share of fossils in the country. Other countries due to concerns about rising levels of greenhouse gas emissions are looking at stricter emissions norms and exploring carbon tax on fuels either through direct taxes or carbon trading programs. Carbon pricing was first introduced by Finland in 1990 followed by Denmark.

Accompanied by a reduction in income taxes, Sweden in 1991 introduced taxes on carbon and sulfur emissions with Norway which applied the highest rate of tax to the oil and gas production sector far above what was achieved by other countries (IISD 21 September 2020). In 2020, The International Maritime Organization sets regulations that will cap the sulfur content in shipping fuel from 3.5% to o.5% by replacing high sulfur fuels with low sulfur compliant fuel and marine gas which will thereby reduce pollution in marine bodies. (Mukherjee, Verma, Tripathy, & Govil, 2019).

Due to economic growth in the developing world, the energy demand has and is expected to increase even more over the next two decades by 1.2% annually even as the consumption in developed nation stagnates. To meet this increasing demand, technological innovations are needed to improve yields of existing fuels and the exploitation of new sources of energy, making technological innovations another key factor in the current transition to renewables. Technology is playing a significant role in the transition to renewables by allowing the lower cost of renewables and making it economically competitive to fossils. In as much as technology is a key factor in the transition, it is also being used in the oil and gas industry to increase the efficiency of fossil fuel systems and increase productivity from fossils. (Mukherjee, Verma, Tripathy, & Govil, 2019).

Growth without energy is another factor that is taken into consideration concerning the mitigation of greenhouse gas emissions. Countries can continue to grow economically and still reach a point where they can reduce their energy consumption. Developing countries do not use more energy per capita and developed countries use more energy per capita than developing ones. Countries with vastly different and similar incomes consume two, three, four, five times more energy between them. (Tsafos, 2018). But in as much as GPD (Gross domestic product) matters, energy subsidies, economic structure, policy, and technology all play a significant role in the transition to renewables.

6 CONCLUSION

In my thesis topic, I did research by studying materials and articles to see if a switch from fossils fuels to renewable energy is possible, how long it will take for the transition, and at what level are we in with the transition to renewables and green energy. Regarding my thesis work, some conclusions can be made one of which is that the availability of renewables alone does not ensure a greener transition. Factors such as production efficiency, cost, technology, and politics come into play to ensure and enhance an effective transition to renewable energy. To address global climate change, the world needs to change its energy systems and reduce its carbon footprint by slowing down the growth in demand for energy and making sure the energy being used has a lower carbon footprint. There should be a future rise in the price of fossil fuels and curbing the subsidies on these fuels so demand will switch to low carbon sources for energy. But this is not the case now because with a growing population the demand for energy keeps increasing and the transition will not be the same for all countries since most countries are still very dependent on fossil fuels for energy. Also, most developing countries lack the technology, finance, management, and governmental policy to explore and exploit their energy resources.

In as much as most countries in the world are stagnant to this change other countries are already in the transition and set a pace and example for other countries. According to IEA, (Robert, P 1998) the use of coal should reduce by half, oil should fall by a quarter, and gas consumption should increase only slightly accounting for 61% of primary energy from fossil fuels by 2040. Based on my work, it can be concluded that the focus on transition is not that energy systems should frequently change but to show that they can change, and, in the world, once newer sources of energy become competitive, the switch or transition can be dramatic. These newer sources are low carbon sources which many countries are into developing and exploiting.

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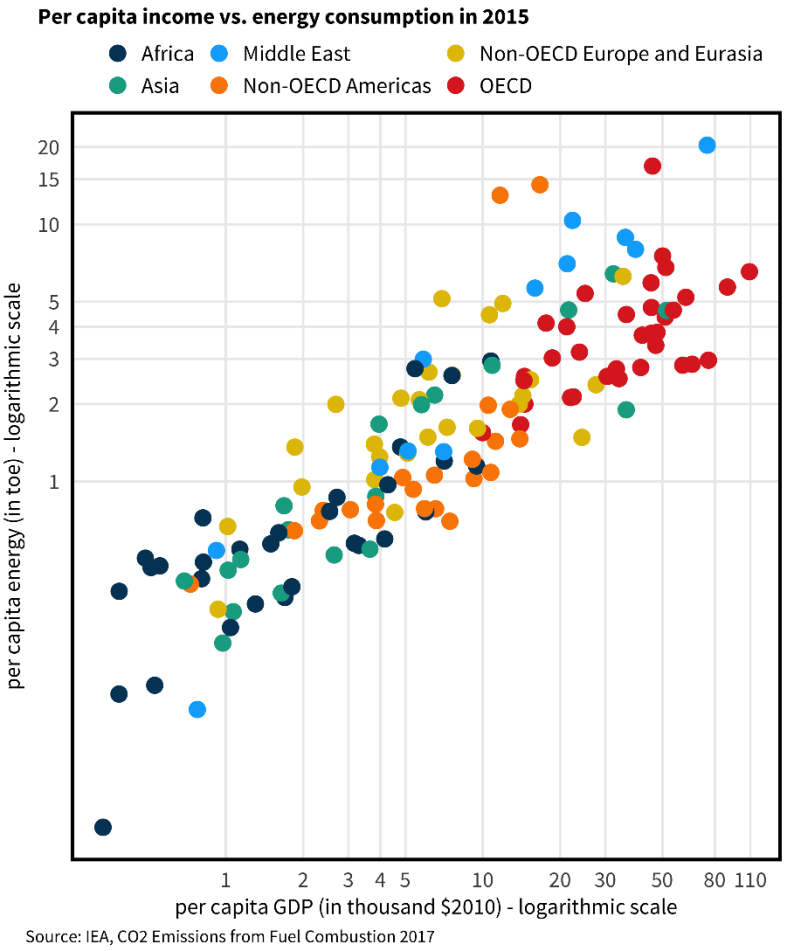
APPENDIX 1



Source: IEA, CO2 Emissions from Fuel Combustion 2017